NATIONAL EXAMS DECEMBER 2008

04-Env-A2
Hydrology and Municipal Hydraulics Engineering

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is a Closed Book exam with a candidate prepared 8.5 x 11 inches double sided Aid-Sheet allowed.

3. Candidates may use one of two calculators, the Casio or Sharp approved models. Write the name and model designation of the calculator, on the first inside left hand sheet, of the exam work book.

3. Any five questions constitute a complete paper. Only the first five answers, to the seven questions, as they appear in your answer book(s) will be marked.

4. Each question is worth a total of 20 marks with the section marks indicated in square brackets [ ] at the end of the question. The complete Marking Scheme is also provided on the final page. *A completed exam consists of five (5) answered questions with a possible maximum score of 100 marks.*

5. The following equations may be useful:

Loop Corrections

$$q_l = -\frac{0.54 \cdot \sum_{loop} \Delta h_i}{\sum_{loop} |\Delta h_i / Q_i|}$$

Node Corrections

$$\Delta H_n = \frac{\sum_{node} Q_i}{0.54 \cdot \sum_{node} |\Delta Q_i / \Delta h_i|}$$

Hazen-Williams

$$V = 0.85 \cdot C_{HW} \cdot R^{0.63} \cdot S^{0.54}$$

Head Loss
D (m), L(m), Q (m^3/s)

$$h_f = \frac{10.68 \cdot L \cdot Q^{1.85}}{C_{HW}^{1.85} \cdot D^{4.9}}$$

1. Provide answers to the following questions related to *components and processes of natural hydrologic systems, precipitation and snow melt.*

    i. Using a basic form of the hydrologic budget equation (below) and considering the complete hydrologic cycle:

    a. Briefly define the terms in the given equation. [3]

    b. Provide a flow diagram indicating the disposition or outcome of *infiltration* and *surface runoff* in a representative watershed. [4]

$$P - R - E - I - G = \Delta S$$

    ii. The storage in a reach of a river is 20,000 m^3 at a given time. Determine the storage in m^3 2-hours later if the average rates of inflow and outflow, during the 2-hours, are 1200 and 1000 m^3/min, respectively. [3]

    iii. Briefly identify and describe two (2) key process variables that need to be taken into account when conducting hydrologic simulation of snow or cold climate precipitation. [4]

    iv. Rain falls at an average intensity of 200 mm/h over a 300 ha watershed for 5 days.

    a. Calculate the average rate of rainfall in m^3/s. [2]

    b. Determine the 5-day volume of rainfall in ha-m. [2]

    c. Determine the 5-day volume of rainfall in mm of equivalent depth over the 300-ha watershed. [2]

2. Provide answers to the following questions related to *conceptual models of runoff, stream flow and hydrograph analysis.*

    i. Briefly describe two (2) important properties of *conceptual models of runoff* and provide one (1) example of how such models can be used to predict stream flow or stream flooding. [5]

    ii. Briefly explain how the relationship between *stream stage* and *streamflow* is constantly changing caused by residential developments along the river bank. In your answer consider two (2) key physical properties of a stream that impact the stage-streamflow relationship. [5]

    iii. A 2-hour storm started at midnight (t= 0 h) and produced 100 mm of rain. The resulting runoff hydrograph from a 50 km^2 drainage area is tabulated below. Calculate the direct runoff in mm from this drainage area and the corresponding runoff coefficient (C). [5]

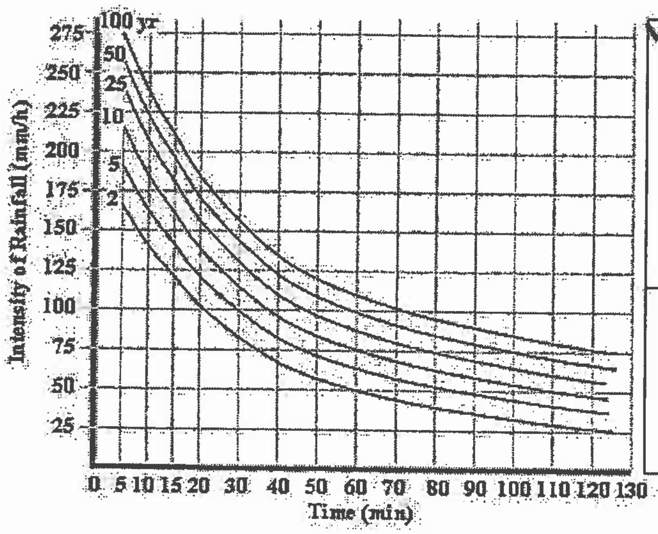
Time (h)	0	2	4	6	8	10	12	14	16	18
Flow (m^3/s)	5	5	20	40	30	25	20	15	10	5

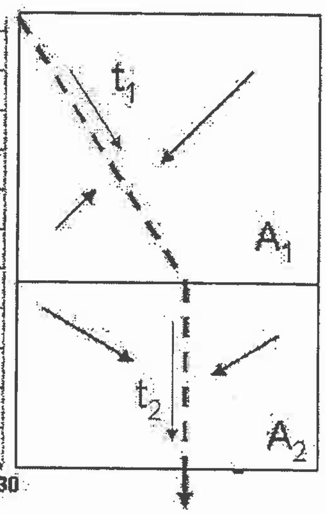
    iv. Briefly describe the four (4) essential steps in the development of a unit hydrograph from an isolated storm event. [5]

3. Provide answers to the following questions related to *storm runoff, infiltration, storm frequency and duration analysis.*

i. Use the Rational Method to calculate the 25-year design runoff for a catchment and IDF curve given below. [5]

Area Label	Area (ha)	Runoff Coefficient (C)	Time of Concentration t (min)
A1	10	0.3	30
A2	5	0.7	15





ii. Annual floods for a small river are reported to follow a normal probability distribution. The 2-year flood for the basin has been estimated as 1100 m^3/s and the 10-year flood as 1500 m^3/s. Using normal frequency factors or similar method, determine the magnitude of the 25-year flood.[5]

iii. Given the following 2-hour unit hydrograph (below) for a drainage basin determine the hourly ordinates of the 4-hour unit hydrograph. [5]

Time (h)	0	1	2	3	4	5	6
Q (m^3/min)	0	90	500	700	350	80	0

iv. Briefly describe the essential steps in generating synthetic unit hydrographs using Snyder' Method *or* the SCS Method *or* Gray's Method. Only one method is to be described. [5]

4. Provide answers to the following questions related to *frequency and probability analysis with application to precipitation and floods*. Based on the annual flood flow records and extreme value frequency factors (tabulated below) do the following:

   i. Calculate the 5, 10 and 50-year return period flood. **[6]**

   ii. Calculate the probability that the annual flood will be greater than 130 m^3/s at least once in the next 10 years. **[6]**

   iii. A fish farm is located downstream of the river and can withstand floods up to 150 m^3/s. It has been calculated that if floods greater than this flow occur once in 10 years, the facility can be repaired and the operation be profitable over the 10 year period. If a larger flood occurs, the fish farm operation will loose money. What is the probability that the fish farm will be profitable in a given 10 year period? **[8]**

Annual Flood Flow

Year	1	2	3	4	5	6	7	8	9	10
Flow(m^3/s)	90	100	120	150	110	80	90	125	130	125
Year	11	12	13	14	15	16	17	18	19	
Flow(m^3/s)	140	135	145	95	115	110	115	125	130	

Extreme Value Frequency Factors (K) for n=19

T_r	10	20	25	50	75	100
K	1.6	2.4	2.5	3.2	3.5	3.8

Recall the following:

Plotting position: $\frac{m}{n+1}$

Risk (R): $R = 1-(1-p)^n$

Probability of Exceedance (p): $p = \frac{1}{T_r}$

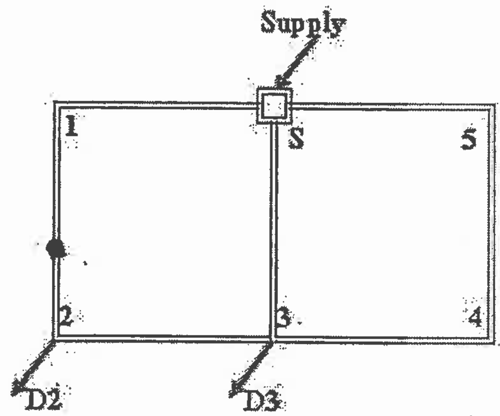
Chow formula: $x = \bar{x} + K \cdot s$

where

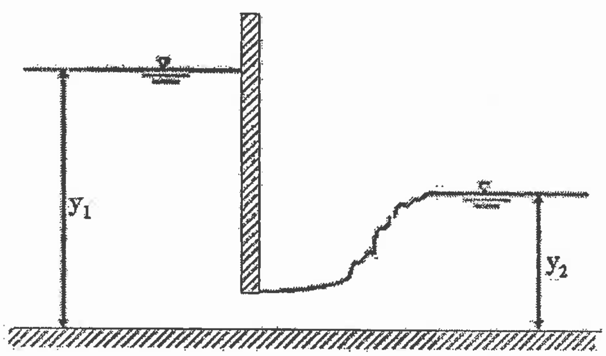
m = rank (largest to smallest)
n = number of years of record
p = probability of exceedance
T_r = return period (years)
K = extreme value frequency factor
$\bar{x}$ = mean flow
s = standard deviation of flow
x = probability flow of interest

5. Provide answers to the following questions related to *hydraulics of closed pipe systems and open channel conveyance under uniform and gradually varied flow and sediment transport.*

   i. A closed pipe system below, all 7-pipes are 450mm in diameter, have a C = 130, are 1000 m long and constructed at 100 m elevation. The total head in the source note (node S) is 200 m. The demand in the two nodes (D2 and D3) is 100 L/s. Calculate the flow in each pipe and the pressure head at node 2 and 3. [7]



   ii. A hydraulic jump occurs downstream of rectangular channel 3 m wide that has an underflow gate as indicated in the diagram below. The water depth before the jump is $y_1 = 2.0$ m and after the jump it is $y_2 = 0.5$ m. Calculate the flowrate [Q (m^3/s)] in the channel and head loss in the jump [H_L (m)]. Assume that the density of water is 1000 kg/m^3. [7]



   iii. Sediment transport can be affected by many factors which can be estimated using the "universal soil loss equation" given below. Identify what the terms refer to (excluding R) and briefly explain how the *soil erosion factor* (R) varies qualitatively for cultivated, grass and forest land uses. Note that E is generally measured in tonnes per square kilometre. [6]

$$E = R \cdot K \cdot L \cdot S \cdot C \cdot P$$

6. Provide answers to the following questions related to *water distribution systems, storage reservoirs, wastewater collection systems and pipe network design.*

   i. A 150 m long, 250 mm diameter pipe is connected to a 100 m long, 150 mm diameter pipe and both are new cast iron pipes (e = 0.26 mm). If the combination of pipes are in series and carry water ($\nu = 10^{-6}$ m^2/s) at 0.06 m^3/s.

      a. Find the head loss in the system in metres (m). [2]

      b. Calculate the length of an equivalent new cast iron pipe of 200 mm diameter pipe. [3]

   The Hazen-Williams equation for equivalent pipes is given below.

$$\frac{L_e}{C_{HWe}^{1.85} \cdot D_e^{4.87}} = \sum_x \frac{L_x}{C_{HWx}^{1.85} \cdot D_x^{4.87}}$$

   ii. A 250 mm diameter, 1000 m long PVC pipeline connects two (2) reservoirs with a 30 m difference in their water level. Find the discharge flow rate (Q) through the pipeline. Note that for PVC pipe e = 0.0002 mm and $\nu = 10^{-6}$ m^2/s. [5]

   iii. Estimate the minimum diameter sanitary sewer to carry a maximum discharge of 100 m^3/d, with a Manning n = 0.013 and a slope s = 2 %. Check to see whether the minimum scour velocity of 0.6 m/s is maintained at water depth of 20% of the pipe diameter. [5]

   iv. Looped networks are generally more reliable than branched networks. Briefly explain three (3) reasons why this is so. [5]

7. Provide answers to the following questions related to *stormwater collection system design, basic pumping applications and urban drainage with runoff controls.*

   i. Briefly describe five (5) principal factors in the design of a minor stormwater collection system serving an urban residential community of about 200 homes. [6]

   ii. A centrifugal pump provides a hydraulic lift of 0.2 m^3/s. The pump inlet diameter is 300 mm and the vacuum pressure at the inlet is 350 kN/m^2. The outlet diameter of the pump is 200 mm and the pressure at the outlet is 150 kN/m^2. Given that the pump outlet is 1 m higher than the inlet and the power of the motor driving the pump is 50 kW, find the efficiency of the pump. The Bernoulli equation with the pump head (h_p) included is given below. [7]

$$Z_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + h_p = Z_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g}$$

   iii. For new urban developments, Ontario regulators require that peak post-development runoff not exceed the pre-development peak runoff. As an engineer you are required by the town to identify three (3) methods of on-site runoff controls and briefly explain how they will reduce the post-development runoff to pre-development levels and at the same time improve the quality of the runoff. [7]

Marking Scheme

1. (i) (a) 3 (b) 4 (ii) 3 (iii) 4 (iv) (a) 2 (b) 2 (c) 2 marks; 20 marks total
2. (i) 5 (ii) 5 (iii) 5 (iv) 5 marks; 20 marks total
3. (i) 5 (ii) 5 (iii) 5 (iv) 5 marks; 20 marks total
4. (i) 6 (ii) 6 (iii) 8 marks; 20 marks total
5. (i) 7 (ii) 7 (iii) 6 marks; 20 marks total
6. (i) (a) 2 (b) 3 (ii) 5 (iii) 5 (iv) 5 marks; 20 marks total
7. (i) 6 (ii) 7 (iii) 7 marks; 20 marks total